DISRUPT THE FUTURE

ENERGY WARRIOR PROFILE

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Researchers at NRL and Pennsylvania State University's (PSU) Air Vehicle Intelligence and Autonomy Laboratory demonstrate autonomous soaring algorithms used to keep unmanned sailplanes aloft for sustained flight durations–a benefit aimed at improving the availability of a 24-7 Information, Surveillance, and Reconnaissance mission data.

Courtesy of PSU

> *"An Energy Warrior is someone who is in tune with how much energy they're consuming and actively working to reduce it."*

Q: WHEN DID YOU BEGIN WORKING ON AUTONOMOUS SOARING, AND HOW DID THIS PROJECT BEGIN?

I actually started looking into autonomous soaring topic when I was an undergraduate at North Carolina State University. A few of us were playing pool and eating pizza, when we had this random idea. Someone asked, "I wonder if an autopilot could soar like a bird." Everyone has seen birds flying around with their wings locked. They use rising air currents to stay aloft. So, we wondered, I wondered—could this be done autonomously with a robot?

Cooperative soaring is a similar approach to that which birds use while in flight. When flying, they often look at each other and try to figure out "hey, if my buddy is going up, maybe I should meander in that direction." In our case, we have two airplanes sharing information, and the information gathered by these two planes is then able to give our whole fleet more capability. And that's our end-goal, to increase warfighting capabilities. Since becoming a full-time researcher at NRL, I've focused on the military application—how do you use autonomous soaring to do something useful for a mission that directly supports our warfighters? I've worked out the mathematics to include a propulsion system in the soaring instrumentation and how to accomplish a notional mission with operational altitude and range constraints with soaring active. I've found that using cooperative soaring makes it quicker and easier to find lift and stay aloft.

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Q: WHY DO YOU THINK DEVELOPING A TECHNOLOGY LIKE AUTONOMOUS SOARING IS IMPORTANT FOR OUR WARFIGHTERS, AND FOR WHAT OUR NAVY IS TRYING TO ACHIEVE?

Autonomous soaring is an example of an energy extraction technique that effectively can offset how much weight Marines carry on their back, and reduce the number of takeoffs and landings they have to do with their Unmanned Aerial Vehicles (UAV). Marines want their UAVs to fly longer, to make fewer takeoffs and landings, to carry fewer batteries, and to spend less time on the ground charging. All of those requests come together if the aircraft can extract energy from the atmosphere. Instead of flying on a battery for only two hours, the UAV is able to keep itself aloft by catching thermal updrafts, turning those two hours of endurance into four or six hours. This directly affects our warfighters' operations. In aviation, the primary drivers are vehicle weight and how much payload the vehicle can carry. A large fraction of the takeoff weight is the onboard energy storage in the form of batteries or fuel. Soaring is a perfect way to remove weight from the aircraft and sustain endurance with less power consumption, which could mean more mass for payload or more power available for the payload. Thus, more warfighter capability comes directly from extracting energy out of the atmosphere.

Q: DO YOU THINK A CULTURAL SHIFT TOWARDS INNOVATION/ENERGY CONSERVATION IN THE NAVY IS IMPORTANT? HOW IS NRL PROMOTING THIS IDEA?

Absolutely. I know NRL participates in the Navy Scientist-to-Sea program, where researchers who might not get out from their laboratory environments very often, get to go onto an aircraft carrier or destroyer and see what the Sailors are doing. We are able to talk to them directly and get valuable feedback. When at sea, I get to watch the eighteen-year-old Sailor push buttons and hear him or her say—"This is a really stupid way to do this. Have you guys ever thought about an automatic mode?" That kind of feedback is really important for us scientists to guide our research.

Q: DO YOU HAVE ANY ADVICE YOU WOULD LIKE TO GIVE YOUNG SAILORS, REGARDING INNOVATION AND CREATIVITY?

Personally, I think the people that are closest to the fight are the ones who can give the best feedback. Those are the men and women that should be looking critically at the systems they have, what their future needs are, and communicating those needs up their chain of command. If a Sailor has an idea on how he/she could improve the performance of a system, those are the kinds of ideas that are really important. From the Navy research and development perspective, we really appreciate when Sailors tell us what works and what doesn't. It's the "what doesn't" that really gets our minds going. Some of the best ideas come from people that have the actual problem. Necessity is the mother of invention.

NRL and PSU combined efforts to demonstrate sustained unmanned, powerless flight of two UAV sailplanes during testing of the solar-soaring and cooperative soaring algorithm-based concepts. From left: NRL team members Chris Bovais, Dan Edwards, and Trent Young, and PSU team members Jack Langelaan, Nate Depenbusch, and John Bird.

Courtesy of NRL

Q: WHY IS INNOVATION AND DEVELOPING CUTTING EDGE TECHNOLOGIES SO IMPORTANT?

I think it was the Chief of Naval Research who said, "We don't want it to be a fair fight. The whole point of innovating is to stay ahead of the next guy." So, we have a mandate to innovate. Technology changes so quickly, that unless you're innovating, you're going to fall behind. One goal of NRL is to look ahead at the next five to 10 years. What can we do, what's coming, and what are the next things that we need to invent? I can only speak for my group, but we look very closely at what the hobby community is developing, what academia is developing, and what the rest of the world is developing. We aggregate all of those things together along with our own expertise to come up with directions for new research that stays ahead of the next developments.

Q: WHAT DOES BEING AN ENERGY WARRIOR MEAN TO YOU?

An Energy Warrior is someone who is in tune with how much energy they're consuming and actively working to reduce it. Some things are very simple and straight-forward, like turning off the lights and your computer at night. From the perspective of unmanned aviation, it's more efficiently using the onboard energy stores. In my case, it's finding ways to extract energy from the atmosphere and from the sun, either through soaring or solar photovoltaics, in order to reduce the use of stored energy.

SAILPLANE

Autonomous Soaring for Unmanned Aerial Vehicles (UAVs)

The Naval Research Laboratory (NRL) is testing autonomous, cooperative soaring concepts for UAVs, exploring energy extraction techniques for enabling UAVs to fly longer on less battery power and fuel.

SUPPORTING OUR WARFIGHTERS

UAV energy harvesting is aimed at improving the availability of a 24-7 **Information, Surveillance, and Reconnaissance (ISR) mission** without using logistics fuel. This will benefit the expeditionary warfighter by enhancing the endurance of existing and future UAV assets. Simply put, the UAV collects ISR normally, and autonomously gains energy from the atmosphere when it can.

HOW DOES IT WORK?

NRL's Dr. Dan Edwards tells us that, by locating and using the naturally occurring air currents known as **thermals**, unmanned aerial vehicles can dramatically extend the duration of flight.

LET'S BREAK IT DOWN

Communication and data sharing between sailplanes allows each computer to make decisions on where to fly, in order to save energy.

1. **Measures vertical wind**

   Changes in airspeed and altitude are measured. Vertical wind appears as unexpected free altitude.

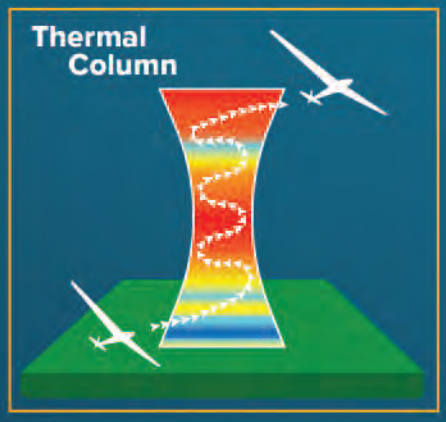
2. **The software**

   The Autonomous Locator of Thermals (ALOFT) algorithm* commands the autopilot to orbit in areas with beneficial vertical winds.

   ** Developed by NRL's Dr. Dan Edwards*

3. **Cooperative autonomous soaring**

   Multiple vehicles can exchange local data of soaring conditions. Using data sharing, the swarm can collectively find thermals more effectively.



It's all about **THE SOFTWARE**

The autonomous soaring technology can be implemented as a software upgrade to any existing UAV autopilots. Initial modeling estimates suggest that a **19 to 20 hour endurance threshold** for a single aircraft is within reach.

TECHNOLOGIES BEING TESTED:

- Photovoltaics
- Autonomous soaring
- High-energy density storage
- Cooperative flight
- Maximum power point tracking (MPPT)

GOAL: To deliver persistent ISR, which operates purely on solar energy.

Improvement with Autonomous Soaring Technology

1,143% increase The aircraft achieved altitudes using thermals to about 5,000 feet

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